Oncology Lifeline – A Timeline Tool for the Interdisciplinary Management of Breast Cancer Patients in a Surgical Clinic.

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Abstract

The multidisciplinary approach to breast cancer treatment in a comprehensive breast center model can deliver a high standard of care for the patient, but it also generates a wide range of patient data that are typically left as disparate silos, and not organized or analyzed for any clinician to help with patient care. We have developed a method for the synthesis of radiology, surgery, pathology, medical oncology, and genetics information from a patient medical history in a timeline paradigm with elements of clinical decision support and quality indicators to help with decision making. A model for structuring data from the many disparate sources was developed to support enriched probing interactions. Summary views of the current knowledge from each discipline were also tightly integrated. To support the surgical management workflow, the prototype lifelines were integrated into existing clinical software, incorporating all the relevant events, decisions, and data elements.

KEYWORDS: Patient timeline, Electronic Health Records, Clinical Decision Support

1. Introduction

As the advances in cancer therapy exploit the ever more focused areas of scientific research, clinical specialists have had to develop a multidisciplinary approach to patient care that integrates their efforts in order to realize the benefits [1]. The increasing use of Electronic Health Record (EHR) systems among these centers represents an opportunity to develop visualizations and clinical decision support (CDS) algorithms to help clinicians deliver the standard of care for their patients [2]. In this work we develop a unifying framework for the analysis and presentation of the data collected by the various disciplines at work at a comprehensive cancer center. The visual paradigm we use is that of the patient timeline, called Lifelines, developed by Plaisant et al [3]. We also worked with ideas developed for the querying and presentation of temporal patient data from the work of Wang et al [4].

The resulting visualization uses each of the various specialties in the comprehensive clinic as timeline dimensions. The primary data that are mapped to each dimension include patient medical information generated by clinical encounters with that specialty. Metadata for each dimension is also included as information such as alerts and recommendations are identified by clinical decision support functionality from any of the included dimensions.

The implementation platform for the tool is the RiskApps software package developed by the collaboration between the University of Massachusetts Lowell and the Massachusetts General Hospital for identifying patients at high risk of developing breast cancer [5]. The RiskApps package is built to be consistent with a modular approach in developing niche solutions with international standards-based interfaces for compatibility [6]. With the screening mammography, high risk genetics, and surgical clinic modules already incorporated, we needed to develop this central hub for interpreting a patient history for the purposes of managing their care.

At the lowest level, the data used in the timeline is a mixture of clinical research data, patient self reported health history, and clinician entered medical knowledge. Processed data and analysis results from previous patient encounters such as structured documents, risk model computations, and management recommendations are also included in the timeline. The visualization also supports interactions for summarizing the current known status for each dimension and its tracking over time.

Ultimately the timeline is meant to support the decision making process surrounding patient care by helping clinicians access the right information when they need it.

2. Methods

The fundamental metaphor of the visualization, like that of Lifelines, is a horizontal timeline. We describe the layout and the data used to provide full patient information across each aspect of

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the patients cancer treatment (see Figure 1). The goal is to provide access to all related information in a time-sensitive manner.

2.1 Cancer disciplines as dimensions and icons as encounters

The data dimensions used in the visualizations correspond to the various disciplines of cancer therapy, each represent by a parallel timeline. Data points are represented as icons that are placed on each axis at the time of occurrence. Icons represent patient encounters with a provider of that specialty. For selected dimensions first tier labels provide a high level description for each encounter appearing on the axis. The specific icons used for each dimension reflect the particular encounter type. For instance, surgery has both consultation and exam icons, while radiology has X-ray and MRI icons for both screening and diagnostic imaging. The border of the icon is used to color encode the significance of findings from an encounter. For example, a red outline around a surgery icon represents a invasive cancer finding, while a green outline around a genetics icon represents a negative genetic test.

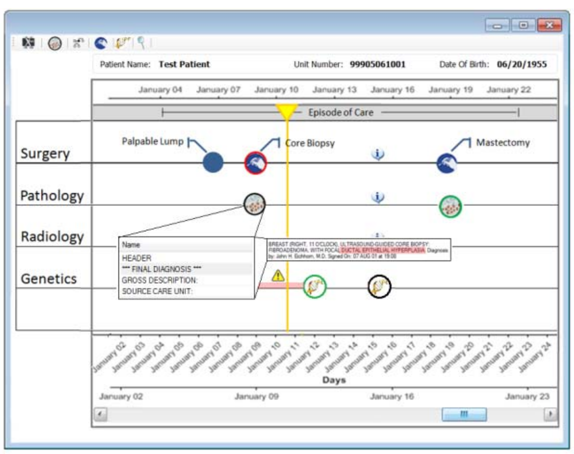

Figure 1. Probing can be used to explore structured documents with key findings highlighted.

2.2 Structured documents and encounter data

The bulk of data content used in the visualization is either patient data collected at an encounter, or a structured document used to report the associated findings. The mechanisms used to probe for additional information reflect this pattern.

Each of the clinical encounters modeled in the system has structured data associated with it. Each dimension has a different data model that it uses to track information and therefore has different content for the timeline and a unique structure for drilling down for additional information.

The documents produced at any given encounter represent an important summary of the current thinking of the clinician at the time, and are very meaningful when trying to understand what has been communicated to the various care givers over the course of a patient's treatment. For example, the system includes a patient survey summary for clinician review in order to summarize the current information provided by the patient as part of an exam, as well as letters meant for the patient's relatives at high risk of BRCA mutation who might want to consider genetic testing. All are available by probing each of the associated icons on the corresponding axis.

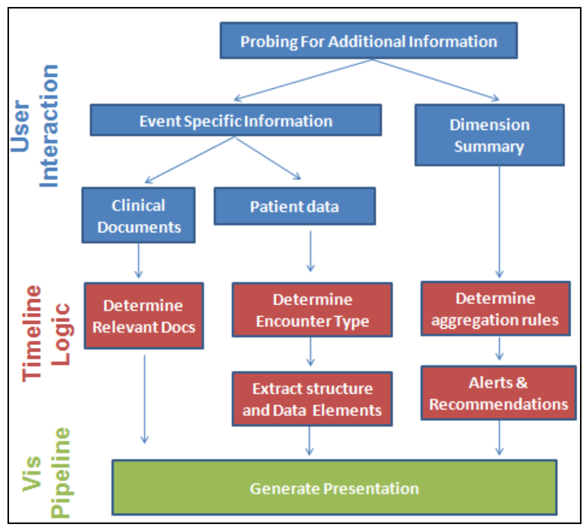

Figure 2. The approach to providing additional data through probing follows a structure for each dimension.

2.3 Anchored axes windows

The timeline visualization also supports a novel interaction with dimensions. When the user places a "tag" icon at a given point in time on an axis, a summary window appears which contains aggregated data with the most important information known at that time. The specific rules for data aggregation and visualization choice for results are left for dimension specific implementations, but the framework for executing the temporal queries and window placement are provided by the timeline.

For the surgical dimension this summary is an instance of a preexisting form that was developed in the surgical scheduling module that displays the definitive surgeries and findings for an episode of care. In the case of the pathology dimension, the summary is a newly developed table indicating the major and minor findings as determined by the natural language processing methods. The genetics dimension has two options for the summary, one is a pedigree showing the risk of a DNA mutation for everyone in the family, the other is a view of the future risk of cancer and the associated management recommendations for various genetic testing outcomes. When an alert or recommendation is encountered by a summary window the information is presented highlighted at the top of the screen.

The window of displayed events on the timeline is set by pan and zoom sliders. There is also an axis marker that denotes the point in time for current view for the summary windows. This marker can be positioned manually or animated with Play-Pause controls so that the summary of each dimension can be observed over time. Additional controls can be provided.

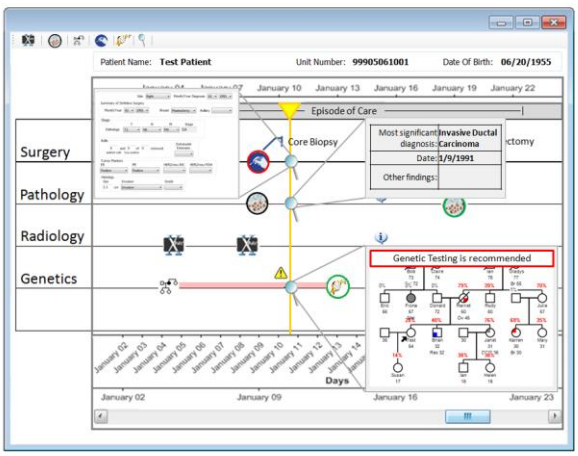

Figure 3. Dimension windows show summary of knowledge of a discipline.

2.4 Data elements

As the data used in this visualization is drawn from multiple clinical specialties, it is naturally heterogeneous. This led to the creation of a structured approach to providing additional information through user interaction that can applied to each dimension (Figure 3). A summary of the corresponding relevant data for the surgical dimension is seen in Table 1.

2.4.1 Surgery

The most robust dimension we have modeled is the surgical timeline. Here we use data from two main categories of patient encounter, the preoperative examination, and the actual surgical visit. It is the surgical visit that provides the physical specimen for the subsequent pathology data. It is often in the examination encounter that family history information is collected, and therefore we often see alerts for genetic testing. For examination encounters we track data for the following major categories: the patient's chief complaint, a history ofresent illness, summary of imaging results, vital signs, medications, allergies, and ultimately what the examination's findings and impressions are. For the surgical encounter we track data such as the date of service, all procedures and codes, and anesthesia.

Techniques to consolidate a prior history of surgeries within an episode of care provide useful data when deciding in the next step in care, automatically staging the cancer for example. Here we identify what the definitive breast and axilla surgeries have been, and what the final histology is along with the extent of nodal involvement and available tumor characteristics.

2.4.2 Pathology

The data from the pathology domain is entirely based on textual reports, and unlike other disciplines there are no patient encounters. The most important aspect of the underlying data is that it is semi-structured. As a result, much information can be easily extracted relatively simply by parsing using regular expressions.

This is a benefit when presenting this data via a probing mechanism because the nested sections of the report are easily parsed and naturally support a drill-down presentation. When the report contains a table of pathological findings consistent with modern synoptic reporting techniques, this parsing approach can also extract the significance of the report. However, a vast majority of the time the structured data falls short of summarizing a reports meaning, leaving much of the interpretation to come from the nuanced language. This problem has largely been solved to by our previous work with natural language processing. We can therefore easily extract the ultimate significance of each pathology report programmatically and expose this knowledge through probing on a pathology icon and drilling down through the structured elements with the areas of text giving rise to significant interpretation highlighted.

The axis window on the pathology discipline shows a table of the summary findings across multiple path reports within the current episode of care. The most important feature is the ability for this view to summarize a collection of multiple pathology reports within an episode of care and illustrate whether this patient has had an invasive diagnosis, a prior finding of a pre-cancerous lesion, or simply a benign finding. In essence, these rules for data aggregation are concerned with synthesizing evidence supporting the presence or absence of a group of major diagnosis types, and subsequently implement a trumping order of diagnoses in which the major findings are reported by order of significance

2.4.3 Genetics

The genetics discipline, specifically the identification and case management of those at high risk for hereditary cancer, was the first piece of the RiskApps platform to use rich visualizations as clinical decision support. As a result, there are many connections between the information tracked here and the connections with the other dimensions. In terms of surgery we find recommendations are made for high risk individuals in terms of prophylactic mastectomy and oophorectomy. In terms of pathology, we find that the tumor staining data made available from the laboratory reports can help us refine our estimates of mutation risk. In terms of radiology, we will make recommendations for enhanced screening with traditional x-ray and MRI for high risk individuals. All of these data are represented as callouts on the timeline and as additional data available from the summary view.

The most clinically significant patient information used in this genetics is typically a family health history. This can be an encounter with a genetics professional, or more commonly a mammography technician in a screening center or nurse practitioner in a surgical clinic that actually collects the data. Probing on these encounters can provide many structured documents to explore. The most basic is the survey summary that shows what data was provided by the patient and what quantitative analysis has been done. More interesting documents include letters to relatives that discuss why they should consider genetic testing.

Placing an axis window on the genetics dimension shows a summary of the family history known to that point as a pedigree with the risk of being a mutation carrier for each individual. This presentation represents the first time a pedigree drawing application has been used to illustrate the results of quantitative models for the entire family in a clinical tool. Placing this presentation on a timeline can let the user appreciate how these emerging patterns of hereditary risk change over time as family history information is collected and refined.

A graph of the future risk of invasive cancer given various genetic testing outcomes is also available. This approach supports the idea of assessing various potential health outcomes given a set of potential decisions about case management. In this context we extend this utility by illustrating the connections these outcomes have for the other dimensions under consideration. An example would be how without genetic testing we might consider enhanced screening, but in the case of a positive genetic testing, surgery is strongly recommended.

2.4.4 Radiology

The RiskApps software doesn't currently manage raw digital image data, and therefore radiology is very similar to pathology in that the bulk of the data used here is from textual reports. There is much structured data that can easily be extracted and correlated with the other dimensions. The first major characteristic is typically whether the encounter is a screening or diagnostic mammogram. A major decision factor from these data is the Breast Imaging-Reporting and Data System classification value. This scale is used by radiologists to differentiate a normal mammogram from those with suspicious findings. As MRI use increases for both diagnostic and high risk screening protocols, there will be more data to manage.

Documents		Encounter Specific Data		Aggregation Rules	Reccemendations
Patient Consent Form	High Risk Referral	Surgery	Consultation/Exam	Episode of Care	Oophorectomy
Meds To Stop	Surgical Summary	Procedure	Chief Complaint	Definitative Breast & Axilla Surgery	Mastectomy
IV Sedation Info	Surgery Results PCP Letter	Description	Imaging Findings	Total Node involvement	
Paravertebral Block Info	Breast Center Report	Anesthesia	Social History	Staging	
Plastic Surgeon Referral	Brief Operative Report	Pretesting	Observations	Final Margins	
Surgical Clinic PCP Letter	New Surgery PCP Letter	Results	Impressions	Tumor Marker Results	
Surgical Clinic Note	Core Biopsy Info Sheet		Orders		

Table 1. Example data elements for the surgical timeline dimension

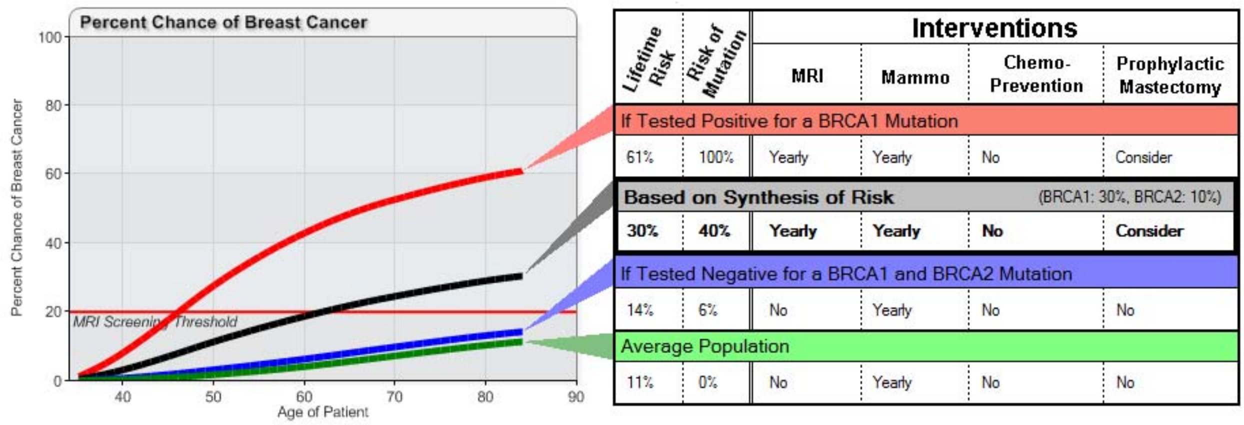

Figure 4. A graph of the future risk of cancer and the various recommendations for the potential outcomes of genetic testing can be selected instead of the pedigree as a genetics summary view.

3. Discussion and future directions

Ultimately, tools that provide timely and relevant information to clinicians can help provide high standards of care for patients. A single vendor of electronic health record systems will likely never capture all of the nuances of each of the many disciplines that are involved in a comprehensive cancer center. Instead, it is likely that each domain will be represented by experts that develop novel approaches to solving their niche challenges. This work is meant to help bring these solutions together in a unified visualization.

One promising extension of this work would be the ability to aggregate multiple patient timelines for a population wide view. This could have potential benefit from both individual patient care and institutional capacity for meeting the standards of care for all patients. An early attempt at visualizing our entire research database of surgical and imaging procedures as a table can be seen in Figure 5. This work was entirely based on our research database of surgical and imaging encounters database.

The first challenge this work points out is the need to aggregate a single patient's history as well as multiple individuals. Another notion shown here is the normalization of the timeline by reporting events as a series of procedure without using their dates for positioning. These two views are both used in epidemiology to describe different types of patient cohorts and should be significant when used to present population wide outcomes data.

N	ProcedureG	seq	Date1	Proc1	Date2	Proc2	Date3	Proc3
1	Imaging	1	2/28/2003	ScrMam				
2	Imaging	1	10/16/2003	ScrMam				
3	Imaging	1	6/13/2003	ScrMam				
4	Imaging	1	5/29/2003	ScrMam				
4	Imaging	2			6/4/2003	DiagMamUni, Ultrasound		
5	Imaging	1	3/27/2003	ScrMam				
5	Imaging	2			4/1/2003	DiagMamUni, Ultrasound		
5	Imaging	3					4/15/2003	DiagMa
5	Biopsy	3					4/15/2003	CoreBx
5	Surgery	4						
6	Imaging	1	6/4/2003	DiagMamBi, Ultrasound				
6	Imaging	2			7/9/2003	DiagMamUni, MRIBi, Ultrasour		
6	Imaging	3					9/22/2003	DiagMa
6	Imaging	4						
6	Surgery	5						
6	Imaging	6						
7	Imaging	1	9/13/2003	ScrMam				
8	Imaging	1	1/30/2003	ScrMam				

Figure 5. A population wide view of all surgical and imaging procedures as a table.

This paper described a visual integration of a multidisciplinary care plan at a comprehensive cancer center. We aimed to highlight the interdependence of decisions on timely data and interpretations. Focusing on developing practical tools for rapid clinical deployment, the RiskApps infrastructure was valuable for use as a comprehensive research database to populate prototype displays.

As a general approach we have aimed at deploying new technology rapidly into the clinic as patient care and not clinical research. For that reason we tend to develop new functionality and abandon early failures as a direct result of clinician feedback, not structured user studies. As this tool now moves from the research and development phase into clinical deployment we expect to make many changes to support workflow integration. The timeline itself should ultimately act as a portal to all of this information, and provides additional perspectives on the data as a whole.

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